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GUIDE FOR TESTING SINGLE-PHASE AC AND UNIVERSAL MOTORS

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Indian Standard
GUIDE FOR TESTING SINGLE-PHASE AC AND UNIVERSAL MOTORS

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Indian Standard
GUIDE FOR TESTING SINGLE-PHASE AC AND UNIVERSAL MOTORS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 22 August 1974, after the draft finalized by the Rotating Machinery Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 The performance requirements of single-phase ac and universal motors are covered by IS : 996-1964*. This standard has been prepared to provide guidance on the test methods for conducting the tests for single-phase ac and universal motors.

0.3 This guide covers methods for conducting the generally applicable tests to determine the performance characteristics of single-phase motors. It is not intended that the standard shall cover all possible tests used in production or tests of research nature. The guide shall not be deemed as making it obligatory to carry out any or all the tests specified in this standard.

0.4 In preparing this guide, assistance has been derived from the following publications:

IS : 4029-1967 Guide for testing three-phase induction motors.

AIEE Publication IEEE No. 114-1958 Test procedure for single-phase induction motors. The Institute of Electrical and Electronics Engineers, New York, USA.

NEMA Standard M.G. 1 Frame assignments for alternating-current integral horse-power induction motors. National Electrical Manufacturers Association, New York, USA.

0.5 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960†.

1. SCOPE

1.1 This guide covers methods for conducting the tests for single-phase ac and universal motors covered by IS : 996-1964*.

*Specification for single-phase small ac and universal electric motors (*revised*).
†Rules for rounding off numerical values (*revised*).

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions given in IS : 325-1970*, IS : 996-1964†, IS : 1885 (Part XXXV)-1973‡ and IS : 2993-1964§ shall apply.

3. ELECTRICAL MEASUREMENTS

3.1 Instrument Selection — The indicating instruments used in electrical measurements shall conform to IS: 1248-1968‖. Instruments with the following accuracy shall be used:

a) For routine tests : Instruments having class of accuracy not inferior to 2·5

b) For type tests : Instruments having class of accuracy not inferior to 0·5

The working range of instruments used shall be so selected as to give indication well up the scale; that is, where a fraction of division is easily estimated and where such a fraction is a small percentage of the value read.

3.2 Instrument Transformers — When current and potential transformers are used, corrections shall be made for ratio errors in current and voltage measurements and for ratio and phase angle errors in power measurements. The use of instrument transformers shall be avoided if possible.

3.3 Voltage — The voltage shall be read at the motor terminals. The supply voltage shall closely approach sine-wave form.

3.4 Power — A single-phase wattmeter shall be used; the preferred arrangement of meters being as shown in Fig. 1. The total watts read on the wattmeter shall be reduced by the amount of $I^2 R$ loss in the voltage circuits of the instruments whenever this loss is a measurable portion of the total watts read.

4. QUANTITIES TO BE MEASURED

4.1 Table 1 gives information about the quantities that are to be measured by means of suitable tests for single-phase ac and universal motors for the different types of motors.

5. INSULATION RESISTANCE TEST

5.1 Insulation resistance shall be measured between individual windings and frame (earth).

5.1.1 The insulation resistance, when the high voltage test is applied, shall

*Specification for three-phase induction motors (*third revision*).
†Specification for single-phase small ac and universal electric motors (*revised*).
‡Electrotechnical vocabulary: Part XXXV Rotating machinery.
§Specification for motor capacitors.
‖Specification for direct acting electrical indicating instruments (*first revision*).

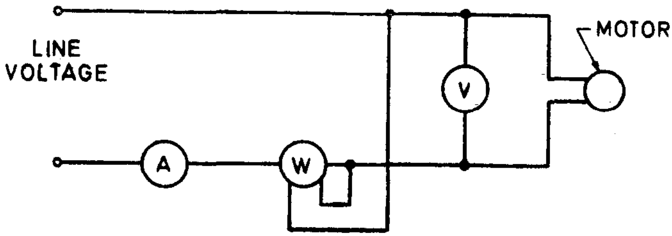


FIG. 1 PREFERRED METER ARRANGEMENT

be not less than one megohm. The insulation resistance shall be measured with a dc voltage of about 500 volts applied for a sufficient time for the reading of the indicator to become practically steady, such voltage being taken from an independent source or generated in the measuring instrument.

NOTE — When it is required to dry out windings at site to obtain the minimum value of insulation resistance, it is recommended that procedure for drying out as specified in IS : 900-1965* should be followed.

6. HIGH VOLTAGE TEST

6.1 A test voltage in accordance with Table 2 shall be applied between the windings and the frame of the motor, with the core connected to the frame and the windings not under test. The test voltage shall be applied once and only once to a new and completed motor in normal working condition, with all its parts in place, and the test shall be carried out together with the insulation resistance test at manufacturer's works.

6.2 Method of High Voltage Test

6.2.1 The test shall be made with alternating voltage of any convenient frequency, preferably between 40 and 60 Hz. The test voltage shall be of approximately sine-wave form and, during the application of voltage, the peak value, as would be determined by spark gap, by oscillograph or by any other approved method, shall be not more than 1·45 times the rms value. The rms value of the applied voltage shall be measured by means of a voltmeter used with a suitable calibrated potential transformer or by means of voltmeter used in connection with a special calibrated voltmeter winding or testing transformers, or by any other suitable voltmeter connected to the output side of the testing transformer.

*Code of practice for installation and maintenance of induction motors (*revised*).

TABLE 1 QUANTITIES TO BE MEASURED FOR SINGLE-PHASE AC AND UNIVERSAL MOTORS

(*Clause* 4.1)

Type of Motor	Locked Rotor Current	Locked Rotor Torque	Pull-Up Torque	Switching Torque	Pull-Out Torque	Speed	Power Factor	Efficiency	Temperature Rise	Capacitor Voltage
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Capacitor (permanent split)	×	×	×		×	×	×	×	×	×
Capacitor (two-value)	×	×	×	×	×	×	×	×	×	×
Split-phase (capacitor start)	×	×	×	×	×	×	×	×	×	×
Split-phase (resistance start)	×	×	×	×	×	×	×	×	×	
Shaded pole	×	×	×		×	×	×	×	×	
Universal*	×	×				×	×	×	×	

*The tests listed apply to operation on alternating current only.

TABLE 2 HIGH VOLTAGE TEST

(*Clause* 6.1)

RATED VOLTAGE OF MOTORS	TEST VOLTAGE (rms)
(1)	(2)
0 volts or less	500
Above 50 volts up to and including 250 volts	1 000

6.2.1.1 It is generally advisable that the high voltage test should not be applied if insulation resistance is less than that specified in the relevant equipment specification.

6.2.2 *Duration of High Voltage Test (Type Test)* — The test shall be commenced at a voltage of about one-third of the test voltage which shall be increased to the full test voltage in accordance with **6.1** as rapidly as is consistent with its value being indicated by the measuring instrument. The full test voltage shall be maintained for one minute. At the end of this period, the test voltage shall be rapidly diminished to one-third of its full value before switching off.

6.2.3 *Duration of the High Voltage Test (Flash Test) (Routine Test)* — As routine test, a test voltage equal to the one specified in Table 2 shall be applied between the windings and the frame of the motor, with the core connected to the frame and the windings not under test for 5 seconds.

6.2.4 *Supplementary High Voltage Test* — If, for any reason, it is desired to conduct additional high voltage tests on a motor which has already passed test in accordance with **6.1** and is installed on site, such additional high voltage tests shall be carried out in accordance with the requirements of **6.1** except that the test voltage shall be 80 percent of the value specified therein. Before applying the supplementary high voltage test, the windings shall be cleaned and the machine thoroughly dried out.

7. RESISTANCE MEASUREMENTS

7.1 General — The following two methods are commonly used for the measurements of resistance.

a) The drop of potential or voltmeter-ammeter method, and
b) The bridge method in which the unknown resistance is compared with the known resistance by using a suitable bridge.

NOTE — Method (*b*) is preferred.

7.1.1 Every possible precaution shall be taken to obtain the true temperature of the winding when measuring the cold resistance. The temperature

of the surrounding air shall not be regarded as the temperature of the windings unless the motor has been standing idle under similar atmospheric temperature conditions for a considerable time.

7.1.2 If the resistance of copper is known at one temperature it may be calculated for any other temperature by using the following formula:

$$R_2 = \frac{(235+t_2) \times R_1}{(235+t_1)}$$

where

R_2 = unknown resistance at temperature t_2 °C, and
R_1 = resistance measured at temperature t_1 °C.

NOTE — If R_1, R_2, and t_1 are known, t_2 may also be calculated from the above formula. Constant 235 is not recognized for all materials; for instant, for aluminium the constant is 225.

7.2 Drop of Potential or Voltmeter-Ammeter Method — In this method, a dc ammeter and a voltmeter shall be used. Simultaneous readings of both voltage and current at motor terminals shall be taken when their values have become steady. The relationship between R, V and I is as follows:

$$R = \frac{V}{I}$$

where

R = resistance in ohms,
V = dc voltage in volts, and
I = dc current in amperes.

7.2.1 Suitable ranges of instruments shall be chosen so that errors of observations are reduced to the minimum. For the measurement of potential drop of less than 0·5 volts, the use of a millivoltmeter is recommended.

7.2.2 The passage of high current may heat the windings appreciably and thus causes erroneous measurement. It is, therefore, recommended that the current be limited to 50 percent of the rated current of the winding.

7.2.3 Care should be taken to compensate for the errors introduced in the measurements by the resistance of leads and contacts. Correction for the current drawn by the voltmeter shall be made if it is appreciable.

7.3 Bridge Method — The resistance above 1 ohm may be determined with sufficient accuracy if a Wheatstone bridge is used. Resistance less than 1 ohm shall be measured by Kelvin double bridge, also known as Kelvin-Thompson double bridge.

7.3.1 *Wheatstone Bridge Method* — In using Wheatstone bridge, the resistance of the ratio arms shall be so selected that the values used correspond as closely as possible to the resistance to be measured; the use of one ohm ratio coil should be avoided. The values of the resistance thus measured

include the resistance of the connecting leads. Therefore, the resistance of the connecting leads shall be subtracted from the total measured resistance; otherwise, it shall be suitably compensated for.

7.3.2 *Kelvin-Thompson Double Bridge Method* — The double bridge compensates for resistance of the leads or other connections. It also enables low resistance to be compared accurately with a standard one of the same order.

8. PERFORMANCE CHARACTERISTICS

8.1 No-Load Test

8.1.1 This test is intended to find out the no-load current, core loss and friction and windage losses.

8.1.1.1 The motor is run at no-load with the running winding(s) excited at normal frequency and voltage until the power input is constant to assure that the temperature of the oil or grease and the bearings has become constant. Readings are taken of volts, amperes and watts input at rated frequency but with voltages ranging from 125 percent of rated voltage down to a point where further voltage reduction increases the current. The voltage adjustment is accomplished preferably by a variable-voltage transformer. Immediately following this test and before the temperatures may change sensibly, a reading of input power P_1 and input current I_A at 50 or 60 percent of rated voltage should be taken with the rotor locked and with only the main or running winding excited. This test should be followed immediately by a measurement of the resistance of the running winding R_1. If the input current at any voltage is I_S, the total copper loss P_C in the machine at the same voltage is:

$$P_c = \frac{I_s^2}{2}\left(R_1 + \frac{P_1}{I_A^2}\right)$$

The copper loss so calculated should be subtracted from the total input power at the same voltage. The resultant values may then be plotted against applied voltage with an extrapolation to zero voltage where the intercept represents the friction and windage losses. Extrapolation of the curve is facilitated by plotting the input power minus the copper loss against voltage squared rather than against voltage.

For most practical purposes the friction can be measured with sufficient accuracy by reading simply the minimum power input as the voltage is reduced and then subtracting the copper loss as calculated by the formula.

8.1.1.2 The friction and windage losses as obtained in **8.1.1.1** shall be deducted from no-load power loss after deducting the copper loss P_c as calculated in **8.1.1.1** for any particular voltage to obtain core loss at the voltage.

NOTE — In the case of shaded pole, these include the losses in the shading coils.

8.2 Locked Rotor Test

8.2.1 It should be recognized that the testing of induction motors under

locked rotor conditions involves unusual mechanical stresses and high rates of heating. Therefore, it is necessary that:

a) the mechanical means of locking the rotor be of adequate strength to prevent possible injury to personnel or damage to equipment.

b) the direction of rotation be determined prior to this test.

c) the current and torque readings be taken at approximately rated voltage and at rated frequency and that the motor be at approximately ambient temperature. The voltage shall be within 5 percent of rated voltage. The ammeter reading shall be corrected by multiplying it by the rated voltage and dividing the product by the voltage read when the ammeter was read. The ammeter shall be read after its pointer has stopped its periodic swinging but all readings shall be taken within 3 seconds after the line switch is closed. The temperature at the start of every test shall be not less than 20°C nor more than 40°C.

8.2.2 *Torque* — The torque may be measured with rope and pulley, by dynamometer or with a brake or beam. All motors are subject to variations in locked rotor torque and these variations depend upon the angular position of the rotor with respect to the stator. The locked rotor torque is defined as the minimum torque developed at rest in the direction(s) of rotation specified and in any angular position(s) of the rotor with the entire motor at a temperature not less than 20°C nor greater than 40°C.

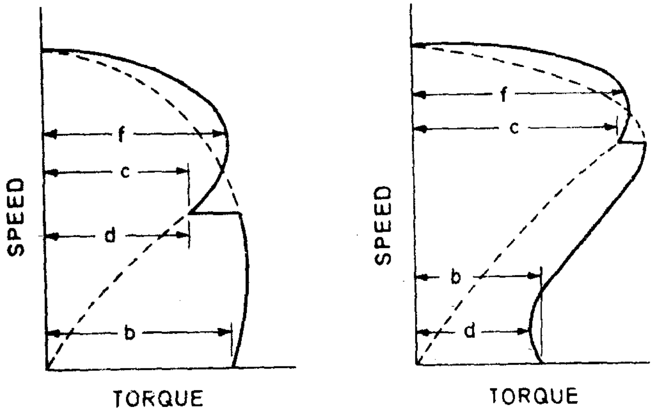
8.2.3 *Power* — Readings of power shall be taken simultaneously with those of current and torque.

8.3 Tests for Speed-Torque and Speed-Current Curves

8.3.1 *General* — The speed-torque characteristic is the relation between torque and speed; embracing the range from zero to synchronous speed. This relation, when expressed as a curve, includes pull out (maximum running) torque, pull-up (minimum running) torque, and locked rotor torque of induction motors (*see* Fig. 2). The speed-current characteristic is the relation between current and speed. (This curve is generally plotted on the same sheet as the speed-torque curve, using a common speed scale for both curves.) The test should be carried out when temperature conditions are stabilized.

8.3.1.1 The speed-torque and speed-current tests may be made with a dynamometer or by rope and pulley methods. Measurements of current, voltage and speed shall be made. Data for these characteristics shall be taken at or near rated voltage.

8.3.2 *Switching Torque* — The switching torque of a motor which has an automatic connection change at some instant in its starting interval is the minimum external torque developed by the motor as it accelerates through switch operating speed. It should be noted that if the torque on the starting connection is never less than the switching torque, the pull-up torque is



b = Locked Rotor Torque
c = Switching Torque
d = Pull-up Torque
f = Breakdown Torque

FIG. 2 TORQUES OF A SINGLE-PHASE INDUCTION MOTOR

identical with the switching torque. However, if the torque on the starting connection falls below the switching torque at some speed below switch operating speed, the pull-up and switching torques are not identical. The difference between pull-up and switching torque is illustrated in Fig. 2.

8.3.2.1 The switching torque may be determined by the following procedure:

The motor is allowed to run at no load and the torque load is gradually increased until the speed falls off abruptly and the starting switch recloses. With this torque setting the motor may either fall off in speed or 'pump', that is, the speed may cycle between the upper and lower speeds. In either case, the torque load should be reduced until the motor transfers and remains on the running connection.

An alternative method is to start the motor from rest with a heavy load and then gradually decrease the torque until the motor transfers and remains on the running connections.

8.3.3 *Pull-Out Torque* — This test may be made by allowing the motor to run light and then increasing the torque until the speed of the motor falls off abruptly. This test should be made as rapidly as is possible, consistent with accuracy, but not so rapidly as to introduce inertia errors into the readings.

8.3.4 *Pull-Up Torque* — The pull-up torque of an alternating current motor is the minimum external torque developed by the motor during the period of acceleration from rest to the speed at which pull-out torque occurs. For motors which do not have a definite pull-out torque, the pull-up torque is the minimum torque developed up to rated speed.

The pull-up torque may be determined by brake, dynamometer, or rope and pulley (*see* **8.4.2**).

8.3.5 *Formula for Load Torque* — The load torque of any motor may be calculated from the following formula:

$$\text{Torque} = \frac{9\,554 \times P}{\text{rev/min}} \text{ Nm}$$

where P is the rated output in kW.

8.4 Load Test

8.4.1 *General* — Load characteristics are obtained by testing a motor as in **8.3** except that the loading is done at least at five points spaced substantially equally from no load to full load and that additional reading of power input and power factor shall be taken to calculate efficiency. Readings beyond full load should be taken as far as possible in the same fashion. It should be ensured that the testing at overload shall not cause injury to the motor. This test shall be carried out at rated or mean voltage and rated frequency.

8.4.2 *Methods of Loading* — The following methods are recommended.

8.4.2.1 *Brake method* — In this method, a brake is mounted on the motor shaft and so arranged that a scale reads the retarding force offered by the brake. The torque is computed from the product of the scale reading and the brake arm length. Care shall be exercised in the construction and use of the brake and the brake pulley.

8.4.2.2 *Dynamometer method* — In this method, the motor is connected to a dynamometer usually by means of flexible coupling. The dynamometer is free to rotate and has a torque arm which rests on a scale. The torque output of the motor is a product of the scale reading and the distance from the centre of the dynamometer to the point where the torque arm makes contact with the scale. To obtain the mechanical power output of a motor by the dynamometer method, the following formula may be used:

$$\text{Power in } P = \frac{T \times \text{rev/min}}{9\,554}$$

where

P = rated output in kW, and

T = torque in Nm.

8.4.2.3 *Rope and pulley method* — In this method, a small rope or cord suspended from a spring scale is wrapped around the motor pulley a sufficient number of times so that when the cord is tightened by a small pull on its free end, the scale measures the motor's pull. If the cord is properly adjusted with negligible tension in the free end, the motor just pulls through the minimum torque points and the scale swing is slow enough so that even the minimum torque in one slow revolution is obtained. This method may be used to test a motor under load, also, if the motor power output is not

great enough to damage the cord. To obtain accurate results, the following conditions shall be fulfilled:

a) No force may be exerted on the free end of the cord unless the magnitude of the force is known and a correction for it is made. A distinct curvature in the free end of the cord as it leaves the pulley is the only conclusive evidence that there is no force.

b) The pulley face should be wide enough to develop the required torque with a single layer of turns of cord. If a single layer is not practicable; multiple layers may be used but the first two turns on the scale end of the cord shall be single layer.

c) The pulley shall be in proper alignment with the scale so that there is no scale error caused by a non-recording component of force in the cord. The alignment shall also be such that there is a clearance between the cord and the pulley flange.

8.4.2.4 *Corrections to be applied* — The following corrections shall be applied:

a) *For cord diameter* (*see* **8.4.2.3**) — In calculating the torque, the radius at which the force applied is to be taken shall be the pulley radius plus half the thickness of the cord. The cord diameter should be measured with the cord under tension. The micrometer anvil and spindle should have flat faces large enough to span at least two strand pitches. Sufficient pressure should be applied to flatten minor irregularities in the cord. In as much as the cord diameter may change because of wear or stretch, the ratio of cord diameter to pulley diameter should be as small as practicable.

b) *For pulley windage loss and for dynamometer windage loss* (*see* **8.4.2.2** and **8.4.2.3**) — The measured values of torque are to be corrected by adding to them a torque corresponding to the pulley windage or the dynamometer windage loss. The allowance for this loss is made by adding a torque T_W:

$$T_W = \frac{K(P_A - P_B)}{S} - T_D$$

where

K = 9·554 when T_W and T_D are in Nm,

P_A = watts input to the motor driving the pulley or dynamometer,

P_B = watts input to the motor without the pulley or dynamometer,

S = speed in rev/min measured at rated output, and

T_D = torque register by the dynamometer when P_A is being measured.

NOTE — T_D is zero when pulley windage torque is to be calculated.

8.4.2.5 *Calibrated machine* — If any of the methods given in **8.4.2.1** to **8.4.2.3** not available, the motor under test may be loaded on a calibrated generator. The efficiency curve of such a generator shall be available.

8.4.2.6 *Uncalibrated machine* — If it is not possible to conduct any of the above four methods, the motor under test may be loaded on an uncalibrated generator.

8.4.3 *Determination of Efficiency*

8.4.3.0 Efficiency is the ratio of output power to input power. Unless otherwise specified, the efficiency shall be determined at the rated voltage, frequency and after steady temperature has been attained at rated output.

8.4.3.1 *Input-output method* — Input-output tests are carried out by the following four methods :

a) Brake method (*see* **8.4.2.1**),
b) Dynamometer method (*see* **8.4.2.2**)
c) Rope and pulley method (*see* **8.4.2.3**), and
d) Calibrated machine (*see* **8.4.2.5**).

8.4.3.2 *Segregated loss method* — Where uncalibrated machine is used, this method is applied. The losses shall include those listed below :

a) *Losses independent of current*
    1) Core loss, and
    2) Friction and windage loss and brush friction loss, if any.
b) *Direct load loss*
    1) Stator copper loss,
    2) Rotor copper loss due to backward and forward components of rotor current, and
    3) Brush contact loss, if any
c) *Stray load loss*
    1) Stray load loss in iron, and
    2) Stray load loss in conductors.

All I^2R losses shall be corrected to a temperature of 75°C.

NOTE — Input-output method is always preferred to segregated loss method.

8.4.4 *Slip Measurement* — For the range of load for which the efficiency is determined, the measurement of slip is very important. Determination of slip by subtracting the value of speed obtained by means of techometer from synchronous speed is not recommended. The slip should be directly measured by one of the following methods :

a) Stroboscope,
b) Slip coil, and
c) Magnetic needle.

Methods (b) and (c) are suitable for machines having a slip of not more than 5 percent.

8.4.4.1 *Stroboscope method* — On one end of the motor shaft a single black radial line is painted upon a white background. The slip is readily measured by counting the apparent backward rotation of the black line over a given period of time.

8.4.4.2 *Slip-coil method* — A suitable slip-coil having approximately 700 turns of 1 mm diameter insulated wire is passed axially over the motor and its two ends are connected to centre-zero galvanometer. When the motor is running the galvanometer pointer will oscillate. The number of oscillations shall be counted only in one direction, that is, to the left or to the right for a period of, say, 20 seconds.

The following formula will give percentage slip:

$$S=\frac{n\times 100}{T\times f}$$

where

S = percentage slip,

n = number of oscillations,

T = time in seconds required for n oscillation, and

f = supply frequency.

8.4.4.3 *Magnetic needle method* — In this method a magnetic needle (suspended on a sharp point so that it can rotate freely) is placed on the body of motor in horizontal plane. The needle will oscillate and the number of oscillations shall be counted for a period of, say, 20 seconds. The percentage slip may be calculated by the formula given in **8.4.4.2**.

8.4.5 *Power Factor Measurement* — Power factor may be measured by one of the following two methods:

a) Watt to volt-ampere ratio, and
b) Power-factor meter.

8.4.5.1 *Watt to volt-ampere ratio method* — Power factor is obtained by ratio of wattmeter readings to volt-ampere readings:

$$\text{Power factor}=\frac{\text{Watts}}{\text{Volts}\times\text{Amperes}}$$

8.4.5.2 *Power-factor meter method* — In this method, power-factor meter is directly connected in the circuit and direct reading is obtained.

8.5 Temperature-Rise Test

8.5.1 This test is intended primarily to determine the temperature-rise on different parts of the motor while running at rated conditions.

8.5.2 While preparing for temperature-rise test, the motor should be shielded from currents of air coming from adjacent pulleys, belts and other machines as incorrect results may be obtained if this is not done. A small

current of air may cause great discrepancy in results obtained. Sufficient floor space should be left between machines to allow free circulation of air. Under ordinary conditions, a distance of two metres is sufficient.

8.5.3 The duration of temperature-rise test is dependent on the type of rating of the motor.

8.5.3.1 For motors with continuous rating, the temperature-rise test should be continued till thermal equilibrium has been reached. Whenever possible, the temperature should be measured both while running and after shut down.

8.5.3.2 For motors with short time rating, the duration of the test should correspond to the declared short time rating. At the end of the test, the specified temperature-rise limits should not be exceeded. At the beginning of the test, the temperature of the motor should be within 5°C of that of cooling air.

8.5.3.3 In the case of motor for periodic duty and for continuous duty with intermittent load, the test should be continued till thermal equilibrium has been reached. Unless otherwise agreed, the duration of one cycle should be 10 minutes, for the purpose of this test. Temperature measurement should be made at the end of no-load period for the purpose of establishing thermal equilibrium. At the end of first half of the last period of no-load operation, the temperature-rise should not exceed the specified limit.

8.5.3.4 For motors designed for specific application (indication mark for this should be included in the nameplate by agreement between the manufacturer and the user), such as fan duty or air conditioner or room cooler duty, etc, where it is difficult to simulate all operating conditions in the laboratory, the testing for temperature-rise shall be done with the motor installed in the unit it is designed for and the test shall be carried out at rated voltage and frequency under severe operating conditions. What constitutes severe operating conditions shall be a matter of agreement between manufacturer and user.

8.5.3.5 For multispeed motors, temperature-rise shall be measured at all speeds and at rated load as in **8.5.3.1**, **8.5.3.2**, **8.5.3.3** and **8.5.3.4**.

8.5.4 When thermal equilibrium is reached, the motor shall be stopped as quickly as possible and measurements taken both while the motor is running and after shut down (wherever possible). No corrections for observed temperatures are necessary if the stopping period does not exceed 30 seconds.

8.5.4.1 In case where successive measurements show increasing temperature after shut down, the highest value shall be taken.

8.5.4.2 Whenever rotor temperature also is required, this is found out by recording the highest temperature reached in the thermometers placed on the rotor bars and core in the case of squirrel cage motors and on winding in the case of wound rotor motor. Thermometers should be applied as soon as rotating parts come to rest.

8.5.5 In cases where the temperature can be measured only after the motor has come to rest (as in case of measurement of temperature-rise by resistance method) the cooling curve is plotted by determining the first points as rapidly as possible. In cases where the first measurement of temperature is made after the periods given in **8.5.4** from the instant of switching off the power, extrapolation of the cooling curve is carried out to determine the temperature at the instant of shut down. This may be achieved by plotting a curve with temperature readings as ordinates and time as abscissa and extrapolating back to the instant of shut down.

8.5.6 *Methods of Measuring Temperature-Rise of Parts of Motor* — The temperature-rise of a part of a motor shall be the difference in temperature between the part of the motor, measured by the appropriate method in accordance with **8.5.6.1, 8.5.6.2** and **8.5.6.3** and cooling medium measured in accordance with **8.5.8.** The commonly used methods for measuring temperature are listed below. It may be desirable to use one of these as a check on another:

a) Thermometer method (using liquid-in-glass thermometer, resistance thermometer or thermocouple);
b) Applied thermocouple method; and
c) Resistance method.

The thermometer method is usually not as accurate as the other two methods for measuring temperatures in small fractional horsepower motors because of the difficulties encountered in properly placing the thermometer. Furthermore, thermocouples do not conduct away as much of the coil heat as thermometers do. The applied thermocouple method is quite often used in conjunction with either the thermometer or resistance method.

8.5.6.1 *Thermometer method* — Liquid-in-glass thermometers, before being used should be examined for broken liquid columns. When the thermometer is in position, the level of its bulb shall not be higher than that of its stem. The bulb should be secured in position with a felt pad, a small piece of putty, or the equivalent, in such a manner as to shield it from the surrounding air. There should be restriction of the natural windage of the motor or of the heat radiation from the coil of which the temperature is being measured. The liquid-in-glass thermometer, resistance thermometer, or thermocouple are applied to the hottest parts accessible without alteration of the structure. The temperature shall be measured on the surface of the coil ends at two peripherily spaced locations.

8.5.6.2 *Applied thermocouple method* — In using this method, thermocouples are applied to the conductor insulation in the hottest parts accessible to them. After being well tucked in, they are covered with a small piece of putty or modelling clay.

8.5.6.3 *Resistance method* — The average temperature throughout a motor winding is determined by comparing the resistance of the winding at the temperature to be determined with the resistance at a known temperature. Extreme care shall be taken to secure accurate resistance measure-

ments because a small error shall cause a comparatively large error in the calculated temperature. The cold resistance shall be taken only after the motor has remained in a constant ambient long enough that the winding is at that ambient temperature:

$$T_h = \frac{R_h}{R_c}(K + t_c) - K$$

where

T_h = total average temperature of winding in degrees Celsius when hot resistance R_h was measured;

R_h = hot resistance in ohms;

R_c = cold resistance in ohms;

t_c = total average temperature of winding in degrees Celsius when cold resistance R_c was measured;

K = 235 for copper, and 225 for aluminium.

Alternatively, the following formula gives the temperature-rise of the winding above cooling air or gas:

$$t_R = \frac{R_h}{R_c}(K + t_c) - (K + t_a)$$

where

t_R = temperature rise in °C of the winding above cooling air or gas,

t_a = temperature in °C of the cooling air or gas at the end of the test, and

the remaining terms as given above.

8.5.7 *Core* — The temperature readings, at a few points on the external surface of the core in at least two peripherily spaced locations near the axial centre line shall be taken. Either thermocouples or liquid-in-glass thermometers may be used.

8.5.8 *Measurement of Cooling Air or Gas Temperature During Tests* — The cooling air temperature shall be measured by means of several thermometers placed at different points around and half-way up the motor at a distance of 1 to 2 metres, and protected from heat radiation and draughts. The value to be adopted for the temperature of the cooling air or gas during a test shall be the mean of the readings of the thermometers (placed as mentioned above), taken at equal intervals of time during the last quarter of the duration of the test.

8.5.8.1 In order to avoid errors due to time lag between the temperature of motors and variations in the cooling air or gas, all reasonable precautions shall be taken to reduce these variations and errors arising therefrom.

8.5.9 *Temperature Correction*

8.5.9.1 *Motors specified for operation at altitudes in excess of 1 000 metres* — For motors specified for operation at an altitude higher than 1 000 metres

but not in excess of 4 000 metres, no correction shall be made if the difference between altitude during test and the specified altitude in service does not exceed 1 000 metres; if, however, the specified altitude exceeds the test altitude by more than 1 000 metres, the specified temperature-rise shall be reduced at a rate of one percent for each increment of 100 metres by which the site altitude exceeds 1 000 metres.

8.5.9.2 *Cooling air temperature for temperature-rise test* — A motor may be tested at any convenient value of cooling medium temperature less than 40°C, but whatever the value of this cooling medium temperature, the permissible rise of temperature shall not exceed, during the test, those specified in the relevant equipment specification.

In the case of motors intended to operate under conditions in which the maximum cooling air temperature exceeds 40°C, the temperature-rise as given in the relevant specification shall be reduced as follows:

a) By 5°C, if the temperature of the cooling air exceeds 40°C by 5°C or less;
b) By 10°C, if the temperature of the cooling air exceeds 40°C by more than 5°C but not more than 10°C; and
c) By agreement, if the temperature of the cooling air is more than 10°C above 40°C.

Tests of temperature-rise may be carried out at any convenient cooling air temperature. When the temperature of the cooling air during test is lower than the stated site cooling air temperature by not more than 30°C, no correction shall be made on account of such differences. When the temperature of the cooling air during test is lower than the stated site cooling air temperature by more than 30°C, the permissible temperature-rise on test shall be the permissible temperature-rise under specified site conditions reduced by a percentage numerically equal to one third of the difference between the specified temperature of the cooling air on site and the temperature of the cooling air on test where both temperatures are expressed in degrees Celsius.

Example :

If the specified temperature of the cooling air on site is 56°C and the temperature of the cooling air on test is 20°C, the reduction in temperature-rise to take account of this difference is:

$$\frac{56-20}{3} = 12$$

The permissible temperature-rise on test is, therefore, $\frac{100-12}{100} = 88$ percent of the temperature-rise on site.

The reductions apply to all the classes of insulation covered in this standard, the test being carried out at the manufacturer's work.

9. MEASUREMENT OF NOISE — (Under consideration).